HYPERSPECTRAL AND FIELD MAPPING OF AN ARCHAEAN KOMATIITE UNIT IN THE PILBARA CRATON, WESTERN AUSTRALIA: APPLICATIONS FOR CRISM MISSION.

A.J. Brown[1], M.R. Walter[1], T. Cudahy[2], [1]Australian Centre for Astrobiology, Macquarie University, NSW 2109, Australia, email:abrown@els.mq.edu.au [2]CSIRO Exploration and Mining, 26 Dick Perry Ave, Technology Park, WA , 6102, Australia

Introduction: Recent VNIR-SWIR airborne hyperspectral investigations of the Early Archaean East Pilbara Granite-Greenstone Terrane have mapped hydrothermal alteration minerals in a predominantly mafic volcanic terrane. The investigation has identified a previously unrecognized aqueously altered komatiite flow. Results of this project are of direct relevance to the forthcoming hyperspectral investigation of the Martian surface by the CRISM instrument, scheduled to launch on MRO in 2005.

Pilbara investigations: In October 2002 a VNIR-SWIR airborne hyperspectral study was commenced by the CSIRO and the Australian Centre for Astrobiology with the goal of mapping hydrothermal alteration patterns throughout a 600 km^2 area of the Pilbara termed the North Pole Dome (NPD). The NPD is largely constituted by volcanic rocks of the 3.5 Ga Warrawoona Group with some minor, but important volcaniclastic interbedded sediments. These sediments have been reported to hold evidence of the Earth's earliest biota [1,2] although this has recently been the subject of much debate in the Astrobiological community [3].

The HyMap instrument [4] was used to collect the airborne hyperspectral dataset. 14 swathes of various lengths and 2km in width were obtained during mid morning on 22 Oct 02. The instrument was flown at approximately 2.5km (8200ft) AMSL. Spectral coverage spanned 450-2500 nanometers in 126 contiguous bands.

Across-track pixel spatial resolution was approximately 5m. This high spatial resolution gives excellent definition of the abundant outcrop of well exposed Archaean rocks. Mapping of individual hydrothermal fluid conduits at the NPD has been possible at this resolution.

CRISM Mission: The first primary mission of the CRISM instrument is to "find new targets of interest: aqueous deposits and crustal composition" [5]. During this part of the mission, CRISM will operate in a hyperspectral, high spatial resolution mode. In addition to this mode of operation, CRISM has a multispectral, lower spatial resolution mode for less intense mapping, and has an Emission Phase Function (EPF) mode to map surface and atmospheric variations to provide information on aerosols, H_2O, CO and ices. Comparisons between the HyMap instrument and CRISM are listed in Table 1. The HyMap dataset most closely approximates the hyperspectral mode of CRISM.

	Instrument and Mode		
	HyMap for Pilbara study	**CRISM Hyperspectral**	**CRISM Multispectral**
Approx. Pixel Size	5m	18-36m	100-200m
Spectral Coverage	447-2477nm	400-4050nm	400-4050nm
Channels	126	570	59
Spatial Coverage	~28x20km	~11x20km @3000 locn	~90% of Mars

Table 1 – Comparison of HyMap characteristics for Pilbara study with CRISM modes

Results: Investigation of the HyMap dataset and fieldwork in the Pilbara has revealed a previously unmapped ultramafic komatiite flow on the east side of the NPD. Microscopic investigation of several samples collected from various locations within the flow has shown serpentine (identified as antigorite by electron microprobe) pseudomorphing olivine. This serpentinisation would likely occur as the following reaction:

$$\underset{\text{olivine(Fo)}}{2Mg_2SiO_4} + 3H_2O = \underset{\text{serpentine}}{Mg_3[Si_2O_5](OH)_4} + \underset{\text{brucite}}{Mg(OH)_2}$$

Accessory minerals within the komatiite include clinopyroxene (diopside). The serpentinization of the flow has enabled the identification of the unit using the distinctive sharp Mg-OH secondary vibrational absorption band at 2.318μm [6]. An example spectrum of the unit is displayed at Figure 1.

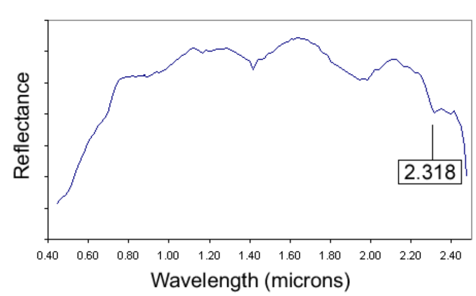

Figure 1 – Example atmosphere-corrected HyMap spectra of of komatiite flow at NPD. Note serpentine Mg-OH absorption band at 2.318μm

Major and trace element analysis has been carried out with XRF (at GEMOC, Macquarie University) on an initial set of three whole rock samples. The average of three samples is shown in Table 2. Whole rock oxygen isotope analysis was carried out at CSIRO North Ryde and is also given in Table 2.

SiO_2	39.1
TiO_2	0.4
Al_2O_3	3.2
Fe_2O_3+FeO	14.7
MnO	0.2
MgO	29.1
CaO	4.0
Na_2O	< 0.07
K_2O	0.1
P_2O_5	0.02
S	< 0.03
LOI	8.5
Cr (ppm)	2949.3
Ni (ppm)	1252.7
Y (ppm)	6.5
Zr (ppm)	23.0
Ce (ppm)	3.5
$\delta^{18}O_{(SMOW)}$	+4.6‰

Table 2 – Arithmetically averaged XRF Analysis of Komatiite samples (N = 3) in wt % unless otherwise stated.

The komatiite flow lies at the base of the ~3.47 Ga Apex Basalt member of the Warrawoona Group [7]. Metamorphism is uniformly low (prehnite-pumpellyite to greenschist) throughout the NPD. Whole rock oxygen isotope values in samples analysed so far suggest that the komatiite unit has not been significantly altered by meteoric waters. The serpentinisation process may therefore have been associated with magmatically derived water.

Komatiites on Mars: Numerous authors have suggested that komatiitic lavas may be a significant rock type on Mars [8, 9, 10]. The amount of olivine in such komatiite flows may be variable. The MGS TES mission has revealed only low global abundances of olivine [11], however this does include an olivine rich 30,000 km^2 region in Nili Fossae [12]. Olivine is present in most SNC meteorites [13].

Serpentinization is the most widespread form of olivine aqueous alteration [14]. The presence of exposed olivine on Mars suggests that surface deposits of serpentine may also be in evidence. Following NASA's directive to 'follow the water', the CRISM mission will likely target serpentine employing its distinctive Mg-OH absorption band. One issue likely to be faced by the CRISM team during the multispectral phase of the mission is how to separate serpentine from chlorite, another aqueous alteration product that posseses an Mg-OH absorption band. Judicious placement of spectral bandpass channels in the 2.3 µm region will allow discrimination of chlorite from serpentine. During the HyMap study, chlorite bearing units have been successfully differentiated from adjacent serpentine rich units. The spatial distributions of these minerals have allowed us to map altered komatiite and basalt flows successfully. If komatiite flows erupted on Mars and were subsequently aqueously altered in a similar manner, the same techniques could be used to help differentiate komatiite from basalt flows using the CRISM hyperspectral or multispectral survey.

Future Research: The hyperspectral and fieldwork study of the NPD continues, and future results are intended to be made available to the public at the project website [15]. By mapping the minerals muscovite/illite, goethite, chlorite and pyrophyllite amongst others, two different Early Archaean hydrothermal events have been mapped at the Dome so far. Modeling of these events to understand the mineral composition of altered greenstones is continuing. Eventually, these models will be translated to a Mars-like environment and the results will be made available in the form of a computer code. It is anticipated the results will be of value to future investigations concerning the effect of hydrothermal alteration on the Martian regolith.

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